ECOLOGY AND EVOLUTION

Srinivasan, Vijayasarathy, and Harold J. Morowitz
The canonical network of autotrophic intermediary metabolism: minimal metabolome of a reductive chemoautotroph 126

CELL BIOLOGY

Vize, Peter D.
Transcriptome analysis of the circadian regulatory network in the coral *Acropora millepora* 131
Ribeiro, Márcia Regina, and John Campbell McNamara
Cyclic guanosine monophosphate signaling cascade mediates pigment aggregation in freshwater shrimp chromatophores 138

DEVELOPMENT AND REPRODUCTION

Arellano, Shawn M., and Craig M. Young
Spawning, development, and the duration of larval life in a deep-sea cold-seep mussel 149
Emlet, Richard B.
The bilaterally asymmetrical larval form of *Stomopneustes variolaris* (Lamarck) 163
Griffin, Frederick J., Edmund H. Smith, Carol A. Vines, and Gary N. Cherr
Impacts of suspended sediments on fertilization, embryonic development, and early larval life stages of the Pacific herring, *Clupea pallasi* 175
Smolensky, Nicole, Melissa R. Romero, and Patrick J. Krug
Evidence for costs of mating and self-fertilization in a simultaneous hermaphrodite with hypodermic insemination, the opisthobranch *Alderia willowi* 188

No. 3: June 2009

BIOLOGY OF MARINE INVERTEBRATE LARVAE

Emlet, Richard B., Svetlana A. Maslakova, Alan L. Shanks, and Craig M. Young
Biological Bulletin Virtual Symposium: Biology of Marine Invertebrate Larvae 201

POSITION PAPERS

Nielsen, Claus
How did indirect development with planktotrophic larvae evolve? 203
Page, Louise R.
Molluscan larvae: pelagic juveniles or slowly metamorphosing larvae? 216

REVIEWS

Moran, Amy L., and Justin S. McAlister
Egg size as a life history character of marine invertebrates: Is it all it's cracked up to be? 226
Forward, Richard B., Jr.
Larval biology of the crab *Rhithropanopeus harrisii* (Gould): a synthesis 243
Metaxas, Anna, and Megan Saunders
Quantifying the "bio-" components in biophysical models of larval transport in marine benthic invertebrates: advances and pitfalls 257

RESEARCH PAPERS

Maslakova, Svetlana A., and Jörn von Döhren
Larval development with transitory epidermis in *Paranemertes peregrina* and other hoplonemerteans .. 273
Wanninger, Andreas
Shaping the things to come: ontogeny of lophotrochozoan neuromuscular systems and the Tetraneuralia concept 293
Bishop, Cory D., and Brian K. Hall
Sniffing out new data and hypotheses on the form, function, and evolution of the echinopluteus postoral vibratile lobe 307
Elia, Laura, Paulina Selvakumaraswamy, and Maria Byrne
Nervous system development in feeding and nonfeeding asteroid larvae and the early juvenile 322
Pochelon, Patricia N., Ricardo Calado, Antonina dos Santos, and Henrique Queiroga
Feeding ability of early zoeal stages of the Norway lobster *Nephrops norvegicus* (L.) 335
Burgess, Scott C., Simon P. Hart, and Dustin J. Marshall
Pre-settlement behavior in larval bryozoans: the roles of larval age and size 344
Krug, Patrick J.
Not my "type": larval dispersal dimorphisms and bethedging in opisthobranch life histories 355
Shanks, Alan L.
Pelagic larval duration and dispersal distance revisited 373

* * *

Index for Volume 216 386

INDEX

A

Algae, 75
Alzheimer's disease, 1
American Samoa, 55
Amphipod, 75
Animal-vegetal axis, 40
Antarctonemertes phyllospadicola, 273
Aquaculture, 23
ARELLANO, SHAWN M., AND CRAIG M. YOUNG, Spawning, development, and the duration of larval life in a deep-sea cold-seep mussel, 149
Asteroid, 322
Autotrophy, 126
AVILA-POVEDA, OMAR HERNANDO, RAFAEL FRANCISCO COLIN-FLORES, AND CARLOS ROSAS, Gonad development during the early life of *Octopus maya* (Mollusca: Cephalopoda), 94
Axon, squid giant, 1

B

"Bathymodiolus" childressi, 149
Behaving in the dark: locomotor, chromatic, postural, and bioluminescent behaviors of the deep-sea squid *Octopoteuthis deletron* Young 1972, 7
Behavior, 7, 257, 344
BERK, WILLIAM, JAKE TEPERMAN, KERRY D. WALTON, KAZUNARI HIRATA, MUTSUYUKI SUGIMORI, AND RODOLFO R. LLINAS, Oral administration of pharmacologically active substances to squid: a methodological description, 1
Benthos, 257
Bet-hedging, 355
The bilaterally asymmetrical larval form of *Stomopneustes variolaris* (Lamarck), 163
Biogenesis, 126
Biological Bulletin Virtual Symposium: Biology of Marine Invertebrate Larvae, 201, 203, 216, 226, 243, 257, 273, 293, 307, 322, 335, 344, 355, 373
Biological rhythm, 131
Biology of Marine Invertebrate Larvae, 201, 203, 216, 226, 243, 257, 273, 293, 307, 322, 335, 344, 355, 373
BISHOP, CORY D., AND BRIAN K. HALL, Sniffing out new data and hypotheses on the form, function, and evolution of the echinopluteus postoral vibratile lobe, 307
Body
  component, 45
  plan, 293
BÖTTGER, S. ANNE, see Charles Walker, 23
BRANDON, C. J., see E. V. Megalou, 103
Brine pool, 149
BROWN, ERIC K., see Gregory A. Piniak, 55
BURGESS, SCOTT C., SIMON P. HART, AND DUSTIN J. MARSHALL, Presettlement behavior in larval bryozoans: the roles of larval age and size, 344
BUSH, STEPHANIE L., BRUCE H. ROBISON, AND ROY L. CALDWELL, Behaving in the dark: locomotor, chromatic, postural, and bioluminescent behaviors of the deep-sea squid *Octopoteuthis deletron* Young 1972, 7
BYRNE, MARIA, see Laura Elia, 322

C

CALADO, RICARDO, see Patricia N. Pochelon, 335
Calcium, 138
CALDWELL, ROY L., see Stephanie L. Bush, 7
Calyculin-A induces cleavage in a random plane in unfertilized sea urchin eggs, 40
Cancer, 23
The canonical network of autotrophic intermediary metabolism: minimal metabolome of a reductive chemoautotroph, 126
Cascade, intracellular signaling, 138
Cephalopod, 7, 94
Chemoautotroph, 126
CHERR, GARY N., see Frederick J. Griffin, 175
Chromatophore, crustacean, 138
Circadian rhythms, 131
Cleavage, 40
Clupea pallasi, 175
Cnidaria, 113
Cold seep, 149
COLIN-FLORES, RAFAEL FRANCISCO, see Omar Hernando Avila-Poveda, 94
Confocal microscopy, 293
Connective tissue
  catch, 45
  mutable, 45
Connectivity, 373
Coral, 55, 68, 131
Correction for Volume 216, Table 1, p. 26, in the article titled "Mass culture and characterization of tumor cells from a naturally occurring invertebrate cancer model: applications for human and animal disease and environmental health." *Biol. Bull.* 216(1): 23–39, 216 (2) iv
Crustacean chromatophore, 138
Cyclic guanosine monophosphate signaling cascade mediates pigment aggregation in freshwater shrimp chromatophores, 138
Cytosolic guanylyl cyclase, 138

D

Deep sea, 7, 149
Development, 293, 322
  indirect, 203
Diel variation in the sizes of larvae of *Bugula neritina* in field populations, 85
Dispersal, 257, 373, 344
  dimorphism of, 355
  scale of, 373
DOS SANTOS, ANTONINA, see Patricia N. Pochelon, 335

E

Early life, 94
Echinoderm, 45, 163, 307
Egg
  adhesive layer, 175
  energy, 226
  sea urchin, 40
  size, 226
Egg size as a life history character of marine invertebrates: Is it all it's cracked up to be?, 226
Electrophysiology, 1
ELIA, LAURA, PAULINA SELVAKUMARASWAMY, AND MARIA BYRNE, Nervous system development in feeding and nonfeeding asteroid larvae and the early juvenile, 322
Embryology,
  herring, 175
  mussel,149

EMLET, RICHARD B., SVETLANA A. MASLAKOVA, ALAN L. SHANKS, AND CRAIG M. YOUNG, *Biological Bulletin* Virtual Symposium: Biology of Marine Invertebrate Larvae, 201
EMLET, RICHARD B., The bilaterally asymmetrical larval form of *Stomopneustes variolaris* (Lamarck), 163
Enteric administration, 1
Environmental health, 23
Erratum for Vol. 216, issue 1, Walker *et al.*, 216 (2) iv
Evidence for costs of mating and self-fertilization in a simultaneous hermaphrodite with hypodermic insemination, the opisthobranch *Alderia willowi*, 188
Evidence that the swim afferent neurons of *Tritonia diomedea* are glutamatergic, 103
Evo-Devo, 293
Evolution, 203, 293, 322

F

Feeding ability of early zoeal stages of the Norway lobster *Nephrops norvegicus* (L.), 335
Feeding preference, 75
Fertilization
  herring, 175
  self, 188
Fish, Pacific herring, 175
Fluorescence, 55, 68
  microscopy, 1
Foraging, optimal, 344
FORWARD, RICHARD B., JR., Larval biology of the crab *Rhithropanopeus harrisii* (Gould): a synthesis, 243
Free spawning, 226
FROST, W. N., see E. V. Megalou, 103

G

GATES, RUTH D., see Caroline V. Palmer, 68
Genetic structure, 373
GIDDENS, HANNAH, see Erik E. Sotka, 75
Glutamate, 103, 113
Glutamatergic transmission in hydra: NMDA/D-serine affects the electrical activity of the body and tentacles of *Hydra vulgaris* (Cnidaria, Hydrozoa), 113
GODA, MAKOTO, SHINYA INOUÉ, AND ISSEI MABUCHI, Calyculin-A induces cleavage in a random plane in unfertilized sea urchin eggs, 40
Gonad development during the early life of *Octopus maya* (Mollusca: Cephalopoda), 94
GRIFFIN, FREDERICK J., EDMUND H. SMITH, CAROL A. VINES, AND GARY N. CHERR, Impacts of suspended sediments on fertilization, embryonic development, and early larval life stages of the Pacific herring, *Clupea pallasi*, 175
Growth and mortality, 257
Guanosine monophosphate, cyclic, 138
Guanylyl cyclase, cytosolic, 138

H

Habitat selection, 344
HALL, BRIAN K., see Cory D. Bishop, 307
HART, SIMON P., see Scott C. Burgess, 344
Health
  environmental, 23
  human, 23
Herbivory, 75
Hermaphrodite, 188
Herring, Pacific, effects of sediment on, 175
Heterochrony, 216
HIRATA, KAZUNARI, see William Berk, 1
Histology, 94
Hoplonemertea, 273
Hormone, red pigment concentrating, 138
How did indirect development with planktotrophic larvae evolve?, 203
Human health, 23
Hydra, 113
Hypodermic insemination, 188

I

Immune response, 68
Immunocytochemistry, 293
Impacts of suspended sediments on fertilization, embryonic development, and early larval life stages of the Pacific herring, *Clupea pallasi*, 175
Indirect development, 203
INOUÉ, SHINYA, see Makoto Goda, 40
Insemination, hypodermic, 188
Intracellular signaling cascade, 138
Introduced species, 373
Isolation-by-distance, 373

J

JERSZYK, EMILY, see Charles Walker, 23
Juvenile, 163

K

KASS-SIMON, G., see J. C. Kay, 113
KAY, J. C., AND G. KASS-SIMON, Glutamatergic transmission in hydra: NMDA/D-serine affects the electrical activity of the body and tentacles of *Hydra vulgaris* (Cnidaria, Hydrozoa), 113
KOSMAN, ELLEN T., AND BRUNO PERNET, Diel variation in the sizes of larvae of *Bugula neritina* in field populations, 85
KRUG, PATRICK J., Not my "type": larval dispersal dimorphisms and bet-hedging in opisthobranch life histories, 355
KRUG, PATRICK J., see Nicole Smolensky, 188

L

Larva
  marine invertebrate, 85, 149, 163, 201, 203, 216, 226, 243, 257, 273, 293, 307, 322, 335, 344, 355, 373
  behavior of, 344
  development of, 273
  herring, 175
  nervous system of, 322
  pluteus, 163
  release of, 85, 243
  settlement of, 355
  size of, 344
Larval biology of the crab *Rhithropanopeus harrisii* (Gould): a synthesis, 243
Larval development with transitory epidermis in *Paranemertes peregrina* and other hoplonemerteans, 273
Lecithotrophy, 355
LESSER, MICHAEL, see Charles Walker, 23
Life
  cycle, 203
  history, evolution of, 203, 216, 226, 355
  origin of, 126
Lipid content, 226
LITVAITIS, MARIANNE, see Charles Walker, 23
LLINAS, RODOLFO R., see William Berk, 1
Low oxygen consumption and high body content of catch connective tissue contribute to low metabolic rate of sea cucumbers, 45

M

MABUCHI, ISSEI, see Makoto Goda, 40
MARSHALL, DUSTIN J., see Scott C. Burgess, 344
MASLAKOVA, SVETLANA A., AND JÖRN VON DÖHREN, Larval development with transitory epidermis in *Paranemertes peregrina* and other hoplonemerteans, 273
MASLAKOVA, SVETLANA, A., see Richard B. Emlet, 201

Mass culture and characterization of tumor cells from a naturally occurring invertebrate cancer model: applications for human and animal disease and environmental health, 23
Mass spawning, 131
Maternal investment, 85
Mating cost, 188
McALISTER, JUSTIN S., see Amy L. Moran, 226
McNAMARA, JOHN CAMPBELL, see Márcia Regina Ribeiro, 138
MEGALOU, E. V., C. J. BRANDON, AND W. N. FROST, Evidence that the swim afferent neurons of *Tritonia diomedea* are glutamatergic, 103
Metabolic
  network, 126
  pathway, 126
Metabolome, 126
Metabolomics, 126
Metamorphosis, 307, 322
METAXAS, ANNA, AND MEGAN SAUNDERS, Quantifying the "bio-" components in biophysical models of larval transport in marine benthic invertebrates: advances and pitfalls, 257
Metazoa, 293
Migration, vertical, 243
Minimal metabolome, 126
Model validation, 257
Mollusc, 23, 94, 103
Molluscan larvae: pelagic juveniles or slowly metamorphosing larvae?, 216
MORAN, AMY L., AND JUSTIN S. McALISTER, Egg size as a life history character of marine invertebrates: Is it all it's cracked up to be?, 226
MOROWITZ, HAROLD J., see Vijayasarathy Srinivasan, 126
Morphogenesis, 273
Mortalin, 23
MOTOKAWA, TATSUO, see Nobuhiro Takemae, 45
MULKERN, JOSEPH, see Charles Walker, 23
Muscle, 293
Mussel, 149
Mutable connective tissue, 45

N

NAKAYA, FUMIO, see Nobuhiro Takemae, 45
Nemertea, 273
Neoplasia, 23
Nephrops norvegicus, 335
Nerve, 293
Nervous system development in feeding and nonfeeding asteroid larvae and the early juvenile, 322
Nervous system, larval, 322
Neurogenesis, 307
Neurons, sensory, 103
NIELSEN, CLAUS, How did indirect development with planktotrophic larvae evolve?, 203
Nitric oxide, 138, 307
NMDA receptor, 113
Not my "type": larval dispersal dimorphisms and bet-hedging in opisthobranch life histories, 355

O

Octopus maya, 94
Olfaction, 307
Opisthobranch, 188, 355
Optimal foraging, 344
Oral administration of pharmacologically active substances to squid: a methodological description, 1
Origin of life, 126
Oxygen consumption, 45

P

p53, 23
Pacemaker, 113
PAGE, LOUISE R., Molluscan larvae: pelagic juveniles or slowly metamorphosing larvae?, 216
PALMER, CAROLINE V., MELISSA S. ROTH, AND RUTH D. GATES, Red fluorescent protein responsible for pigmentation in trematode-infected *Porites compressa* tissues, 68
Paranemertes peregrina, 273
Pelagic larval duration and dispersal distance revisited, 373
Pelago-benthic life cycle, 216
Pericalymma larva, 216
PERNET, BRUNO, see Ellen T. Kosman, 85
Phototaxis, 243
Pigment translocation, 138
Pigmentation, 68
PINIAK, GREGORY A., AND ERIC K. BROWN, Temporal variability in chlorophyll fluorescence of back-reef corals in Ofu, American Samoa, 55
Planktonic duration, 257
Planktotrophy, 203
Plant secondary metabolites, 75
Pluteus, 163
POCHELON, PATRICIA N., RICARDO CALADO, ANTONINA DOS SANTOS, AND HENRIQUE QUEIROGA, Feeding ability of early zoeal stages of the Norway lobster *Nephrops norvegicus* (L.), 335
Poecilogony, 355
Pre-settlement behavior in larval bryozoans: the roles of larval age and size, 344
Predator avoidance, 243
Proximal content analysis, 226

Q

Quantifying the "bio-" components in biophysical models of larval transport in marine benthic invertebrates: advances and pitfalls, 257
QUEIROGA, HENRIQUE, see Patricia N. Pochelon, 335

R

Recruitment, 373
Red fluorescent protein responsible for pigmentation in trematode-infected *Porites compressa* tissues, 68
Red pigment concentrating hormone, 138
Reductive
  citric acid cycle, 126
  tricarboxylic cycle, 126
Rhythm
  biological circadian, 131
  in larval release, 243
Rhythmic potential, 103
RIBEIRO, MÁRCIA REGINA, AND JOHN CAMPBELL McNAMARA, Cyclic guanosine monophosphate signaling cascade mediates pigment aggregation in freshwater shrimp chromatophores, 138
Rhithropanopeus harrisii, 243
ROBISON, BRUCE H., see Stephanie L. Bush, 7
ROMERO, MELISSA R., see Nicole Smolensky, 188
ROSAS, CARLOS, see Omar Hernando Avila-Poveda, 94
ROTH, MELISSA S., see Caroline V. Palmer, 68
Rudiment, 163

S

Sacoglossan, 355
SAUNDERS, MEGAN, see Anna Metaxas, 257
Sea cucumber, 45
Sea urchin, 40, 163
Seawater temperature alters feeding discrimination by cold-temperate but not subtropical individuals of an ectothermic herbivore, 75
Seaweed, 75
Secondary metabolites, plant, 75
Sediment, effects of suspended, on herring, 175
Self-fertilization, 188
SELVAKUMARASWAMY, PAULINA, see Laura Elia, 322
Sensory neurons, 103

Settlement, 257
SHANKS, ALAN L., Pelagic larval duration and dispersal distance revisited, 373
SHANKS, ALAN L., see Richard B. Emlet, 201
Shaping the things to come: ontogeny of lophotrochozoan neuromuscular systems and the Tetraneuralia concept, 293
Size, larval, 85, 344
SMITH, EDMUND H., see Frederick J. Griffin, 175
SMOLENSKY, NICOLE, MELISSA R. ROMERO, AND PATRICK J. KRUG, Evidence for costs of mating and self-fertilization in a simultaneous hermaphrodite with hypodermic insemination, the opisthobranch *Alderia willowi*, 188
Sniffing out new data and hypotheses on the form, function, and evolution of the echinopluteus post-oral vibratile lobe, 307
SOTKA, ERIK E., AND HANNAH GIDDENS, Seawater temperature alters feeding discrimination by cold-temperate but not subtropical individuals of an ectothermic herbivore, 75
Spawning, development, and the duration of larval life in a deep-sea cold-seep mussel, 149
Spawning, mass, 131
Spiralia, 293
Squid, 7
  giant axon, 1
SRINIVASAN, VIJAYASARATHY, AND HAROLD J. MOROWITZ, The canonical network of autotrophic intermediary metabolism: minimal metabolome of a reductive chemoautotroph, 126
Stress, thermal, 75
SUGIMORI, MUTSUYUKI, see William Berk, 1
Symposium: Biology of Marine Invertebrate Larvae, 201, 203, 216, 226, 243, 257, 273, 293, 307, 322, 335, 344, 355, 373

T

TAKEMAE, NOBUHIRO, FUMIO NAKAYA, AND TATSUO MOTOKAWA, Low oxygen consumption and high body content of catch connective tissue contribute to low metabolic rate of sea cucumbers, 45
Temperature, 55
Temporal variability in chlorophyll fluorescence of back-reef corals in Ofu, American Samoa, 55
Tentacle pulse, 113
TEPERMAN, JAKE, see William Berk, 1
Thermal stress, 75
Transcriptome analysis of the circadian regulatory network in the coral Acropora millepora, 131
Transitory epidermis, 273
Translocation, pigment, 138
Transmitters, 103
Transport, 257, 373
Tritonia, 103
Trochophore, 216
Trochozoa, 293

V

Veliger, 216
Vertical migration, 243
VINES, CAROL A., see Frederick J. Griffin, 175
VIZE, PETER D., Transcriptome analysis of the circadian regulatory network in the coral *Acropora millepora*, 131
VON DÖHREN, JÖRN, see Svetlana A. Maslakova, 273

W

WALKER, CHARLES, S. ANNE BÖTTGER, JOSEPH MULKERN, EMILY JERSZYK, MARIANNE LITVAITIS, AND MICHAEL LESSER, Mass culture and characterization of tumor cells from a naturally occurring invertebrate cancer model: applications for human and animal disease and environmental health, 23
WALKER, CHARLES S., ANNE BÖTTGER, JOSEPH MULKERN, EMILY JERSZYK, MARIANNE LITVAITIS, AND MICHAEL LESSER, Correction for Volume 216, Table 1, p. 26, in the article titled "Mass culture and characterization of tumor cells from a naturally occurring invertebrate cancer model: applications for human and animal disease and environmental health." *Biol. Bull.* 216(1): 23–39, 216 (2) iv
WALTON, KERRY D., see William Berk, 1
WANNINGER, ANDREAS, Shaping the things to come: ontogeny of lophotrochozoan neuromuscular systems and the Tetraneuralia concept, 293

Y

YOUNG, CRAIG M., see Emlet, Richard B., 201; Shawn M. Arellano, 149

Z

Zoea, 335
Zooxanthellae, 55